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OBESITY

II. Food Intake and Energy Requirements

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OBESITY
II. Food Intake and Energy Requirements

The preceding issue of this Review dealt with the incidence and significance of obesity, and with methods for its measurement.

The present Review is concerned with the physiology and etiology of obesity. There have been many theories concerning the cause of obesity. These have included the effects of the various endocrine glands, derangements of the metabolic chemistry, changes in the efficiency of food absorption and utilization and others. The literature on this subject has been controversial due, on the one hand, to an improper control of experiments and, on the other, to neglect of important experimental factors.

In the last ten years or so, many of these earlier theories have been disproved. Even today, considerable confusion exists concerning the physiology and chemistry of obesity and of means for its control. Despite this confusion, the relationship between obesity, food intake and energy requirements has been clearly established. The control of obesity must come, therefore, from an appreciation of these relationships.

Interrelations Between Food Intake, Energy Metabolism and Obesity:

It is clearly recognized today that obesity results from an imbalance between food intake and energy output. It may be of value, nevertheless, to briefly review some factors in this relationship.

Let us consider a normal adult individual whose body weight and composition remain constant over a period of time. The food intake plus water and oxygen must equal in mass the body output of carbon dioxide, water, indigestible residue, urea, phosphate, sulfate and so on. This is simply an expression of the law of conservation of mass.

The excreted carbon dioxide, water and other products need not come directly from the food ingested. It is clear from the many experiments of Schoenheimer (1) and of others that ingested food, in the course of intermediate metabolism, exists in a state of dynamic interaction with body tissue constituents. Thus, a given molecule of exhaled carbon dioxide may result from an intermediate derived from ingested carbohydrate, protein or fat. Or it may arise through an intermediate originating from depot fatty acids, muscle glycogen stores or tissue protein participating in the metabolic turnover. For any metabolic degradation of body tissue — fat, carbohydrate or protein — however, an equal amount must have been synthesized in order for the overall body mass and composition to remain constant.

A gain in body weight results when the mass of the food intake exceeds that of the excreted products, the difference being stored in the body. In this case, also, the excreta originate from both food and from body tissue, but the overall net difference remains as an increment in body weight.

What determines, in one case, a balance between mass intake and output and, in a second case, an imbalance — in which the mass output is less than that of the mass intake? The amount of metabolic activity in the body, i.e., the extent of reactions such as oxidation, decarboxylation, deamination, degradation and others, is apparently controlled by the amount of energy expended or dissipated by the body. The mechanism of the control is not clearly understood. Nevertheless if, for example, a quantity of energy of 3,000 Calories is expended by the body, either as heat or in mechanical work, then it must follow that only such an amount of net metabolism can take place as will produce 3,000 Calories. If in the period of time that the 3,000 Calories were expanded, an amount of food was eaten whose complete metabolic oxidation would produce more than 3,000 Calories, the entire quantity of food — or equivalent of body tissue — is not completely metabolized. A fraction of the resulting intermediate products is metabolized completely and excreted. Another fraction remains in the body and, depending on the state of the body at the time and the type of food, is stored either as muscle glycogen or, predominantly, as fat.

Conversely if, for a given period of time, the energy expenditure of the body is greater than that provided by the metabolism of ingested food, then body tissue — fat, glycogen or even protein — must be metabolized in addition to the ingested food to produce the amount of energy necessary to make up the deficit.

The mechanism whereby an increased energy output increases the extent of metabolism is not clearly understood. In the body tissues of an individual there exists a steady state condition of constant change and interchange comprising all the reactions characteristic of intermediate metabolism. These spontaneous reactions are accompanied by a net evolution of heat. More accurately, from the thermodynamic standpoint, spontaneous reactions are accompanied by a decrease in "free energy." In order to maintain the body temperature constant, the heat is carried away by the blood which acts as a heat exchange medium and is eliminated via the skin and lungs.

It is to be emphasized that heat production is in all cases the result of chemical reaction and represents the difference in heat content between reactants and products. These spontaneous reactions will take place to a considerable extent even in the absence of muscular activity simply because of the juxtaposition of reactant metabolites and of enzyme catalysts.

In muscular activity, the free energy change of metabolic reaction is coupled to the mechanical energy of muscle fiber contraction, e.g. through

the ATP-myosin system (2). If, as a result of nervous or humoral stimulus, muscle activity increases, reactions take place in the muscle tissue which, in turn, induce changes in the metabolic steady state. Whether these reactions take place as a result of mass action effects (i.e., withdrawal of products to induce a shift in an equilibrium) or otherwise is not known.

In any event, the steady state condition is shifted so that more of the "metabolic pool" constituents are degraded and finally eliminated as carbon dioxide, water and other products. In turn, this shifts the equilibrium from tissue components (fatty tissue, for example) to the pool of intermediates.

No one today would dispute the statement that for any individual, overweight results only from eating more than is required to provide for the energy expended by his body. The situation is not nearly so clear with respect to the differences between individuals which determine why some become overweight and others do not. Recent studies have contributed much toward an understanding of these differences and of their causes.

Balance Between Food Intake and Energy Expenditure:

Why do some individuals limit their food intake to that necessary to supply the energy output of their body? Why do others eat more than is necessary for this purpose? The mechanism which controls appetite to produce satiation and limitation of food intake is still not clear today, although a number of factors have been involved with considerable certainty. Three factors which have been shown to be of major importance in controlling food intake are the "four H's," Heredity, Habit, Hypoglycemia and the Hypothalamus.

Hypothalamus: The importance of the hypothalamus in the mechanism for appetite regulation is shown by the striking effects produced by injury to this region of the brain. Numerous studies have shown (3) that injury to the hypothalamus, whether accidental or deliberate, causes obesity to occur as a result of voracious appetite. This begins abruptly after the injury and leads to food intakes from two to three times greater than normal. In addition to this enormous increase in appetite, hypothalamic injury is often accompanied by reduced physical activity as well, thereby further accentuating the tendency to overweight. Numerous cases in the medical literature have been reported in which obesity occurs following diseases such as tumors of the pituitary (Froelich's syndrome (4)), encephalitis (5) and injury to the brain. More intensive work on these diseases show clear indications that the obesity is secondary to hypothalamic injury in these various instances (5, 6, 7). This, in turn, causes increases in food intake. As an indication that metabolic disorders are not involved directly, it has been shown that animals

which became overweight following hypothalamic injury lost weight when food intake was reduced (8).

Hypoglycemia: Hypoglycemia is often associated with hunger and increased food intake. This condition frequently occurs as a result of insulin imbalance, either because of tumor activity in the islet cells of the pancreas or through insulin therapy (9, 9a). Contradictory findings have been reported relating hypoglycemia to appetite. Apparently, rapidly developing hypoglycemia of short duration does not stimulate appetite, while long-continued, increasingly severe hypoglycemia does (10). Since hypoglycemia is rarely observed in the obese (11), it is difficult to ascribe the development of obesity to this cause.

In very recent studies, Mayer and Bates (12) conducted a series of experiments with large numbers of rats, dogs and mice in an attempt to correlate variations of the blood level of several metabolites with food intake. Solutions of various sugars, amino acids and fat emulsions were administered subcutaneously or intravenously with saline solutions used as controls. Insulin and epinephrine were used to modify glucose levels. It was found that variations of food intake were strikingly correlated to variations of blood glucose and were influenced by other metabolites only insofar as their administration caused direct or indirect variations of blood glucose. Mayer and Bates believe that the glucose level in the blood is related to food intake indirectly by affecting the hypothalamus, suggesting a change in the ATP concentration in the hypothalamus as the intermediate mechanism involved.

From these as well as the preceding observations, it may be concluded that although the hypothalamus obviously plays an improtant part in regulating food intake, its exact relation to the development of obesity in apparently normal individuals has not been definitely established. It may be that some mechanism exists in obese individuals in which, whether through blood sugar or other mechanisms, the hypothalamic activity is altered, so that food intake is left without proper control.

Heredity and Habit: The importance of heredity in obesity is shown by statistics which indicate that where both parents of an individual are overweight there is a 73 per cent chance of the individual's becoming overweight; whereas if only one parent is overweight, there is a 40 per cent chance of the individual's becoming overweight. If both parents were of normal weight, then only about 9 per cent of the children become obese (13).

It is a common complaint of fat people that they have inherited their overweight condition. Until very recently, it was believed that heredity influenced overweight by influencing eating habits. Thus, eating habits and attitudes towards food learned from one's elders may determine whether obesity will occur in later life. Recent experiments with mice have shown

several significant results which indicate the influence of additional factors. First, it has been shown that there are strains of mice who become obese as a result of hereditary influences (14). Further studies with such mice have shown that the obesity occurs as a result of increased Calorie intake (15), primarily because of an increased tendency to choose a diet rich in fats (16) and consequently of high caloric value.

Other Habits and Customs: In modern civilization eating has taken on many functions other than that of its primary biological purpose of providing building materials and fuel for life processes. In many cultures, and up until recently, in our own, overweight was considered desirable, as a sign of affluence and of good nourishment. Even today, food is forced on many children in the mistaken belief that a fat child is a healthy child. Lunch and dinnertime often are used for purposes of business transaction and for social functions. Food intake is increased at cocktail parties, bridge parties and the like and hosts vie with each other to provide more tasty, appealing and more bountiful appetite-tempters. Cocktails, other alcoholic beverages and soft drinks constitute additional insidious ways of piling up extra, unnecessary Calories. Obesity in later years often is the result of persistence in the eating habits of younger life. Quantities of food which in youth served to supply the energy output of vigorous exercise and activity continue to be eaten even though diminution in activity and energy expenditure now result in a decreased need for food. The excess is stored as fat.

Psychological Factors: It has been clearly recognized that over-eating leading to obesity is very often caused by psychological disturbances. Studies by Bruch, especially, (17, 17a) show the importance of factors such as insecurity, disappointment and worry in causing overeating in children. Adults also find temporary solace in eating when they have difficulty in struggling with emotional problems. "For them, food acts as a balm, as alcohol does for others who find life too hard" (18). Compulsive eating to excess is a means of refuge and escape. Many people eat candy and other snacks between meals, out of boredom, while others smoke or chew gum.

In the treatment of obesity, also, these factors must be considered. Physicians commonly find that people who go on diets and lose weight, very often quickly revert and regain all the lost weight. Unless the initial drives making for overeating are understood and dealt with, no permanent relief from obesity may be expected. The importance of psychotherapy as an approach to the problem of obesity is indicated by the fact that weight reduction, accompanied by psychotherapy, is more successful and permanent (19).

A real boost to the morale of would-be reducers has been achieved through the advent of a group of obesity clinics which have sprung up throughout the country. These clinics, working on the same principle as Alcoholics Anony-

mous — and often dubbed, "Fatties Anonymous" — help maintain the spirit and will to continue on sensible reducing diets. Members of these groups are referred, after thorough preliminary physical examinations, by physicians. Meetings are usually held once a week over at least a nine or ten week period and feature lectures by nutritionists, stylists, and others who provide inspiration and scientific reason for maintaining normal weight. The spirit of competitiveness contributes further to the achievement and maintenance of weight reduction. Members are "weighed in" at each meeting. If they have lost weight, they described how they have been able to do so; if they have gained weight, they must give an accounting therefor!

Food Utilization: Lean people utilize food to the same degree of efficiency as do fat people. The amount of food eaten does not become significant as a source of calories until it is absorbed through the intestinal mucosa and enters into the metabolism of the body. Because of this it was thought that there might exist a difference between lean and obese persons in the efficiency of food absorption and utilization. Such a difference would serve to account for the development of obesity in certain individuals on an apparently "average" diet. Experimental studies investigating this point, however, have demonstrated that no such difference exists (20), thus further emphasizing the fact that an excess intake of Calories is the factor causing obesity.

A major problem faced by physicians dealing with obesity concerns the difficulty of obtaining reliable information about food intake (21). Obese patients often insist that they eat very little, but when adequate control is exerted over dietary intake (such as is done in a metabolic ward), weight loss proceeds as expected.

Detailed questioning is often required to reveal the extent of food intake. People will not report food that they do not eat, but often forget to list significant quantities of food that they have eaten. Some people report a given quantity of food as a small portion; others would consider the same amount an adequate or large serving. Without actual measurement or weighing of the food, reports of food intake may be grossly inadequate.

Energy Expenditure:

The second major factor to be considered concerns the total energy expenditure of the individual. This comprises the sum of heat and work output. Customarily these are considered under such headings as basal metabolism, specific dynamic action and muscular activity, although the independence of these from each other is open to some question.

A great deal of effort has gone into the development of data concerning individual Calorie requirements for each of these headings and their relation to such factors as age, height, weight, sex, dietary composition, type of work

and the like. The method of summation of the various factors in energy output to give a value for the over-all energy output is widely practiced. Nevertheless, this method may be quite inadequate and may lead to gross errors in estimating the Calorie requirements for a given individual or group (22).

Thus, in some studies (23) a comparison of food intake versus elaborately computed Calorie requirements indicated that 55.3% of a group of 272 secondary school students were undernourished. Actual examination of the group revealed however, that only 11.1% were underweight, while 47.7% were overweight by 7.5% or more.

Such inaccuracy makes difficult the *a priori* prediction of the Calorie adequacy of a given diet, as well as the construction of effective diets for weight maintenance and control. Some of the factors leading to such inaccuracy are discussed below.

Basal Metabolism: Basal metabolism is the major factor, in most individuals, in energy expenditure. For example, in persons engaged in sedentary to moderate activity, the total daily Calorie output ranges from 2000 to 3000 Calories, while the basal metabolism of such persons varies from 1200 to 2000 Calories, or roughly, two-thirds of the total. In view of this, it may be of value to review certain basic information concerning the basal metabolism.

First, the basal metabolic rate does not represent a minimal metabolic activity but rather the heat output (usually measured by the amount of oxygen consumed) under certain "standard" (24) or specifically defined conditions, namely in the morning, from 12—14 hours after the last meal, while the subject is lying down, motionless. That the basal metabolic rate as ordinarily measured is not *minimal* is shown by several factors: (1) Heat output during sleep is about 10 per cent less than that obtained during the resting state during which the basal metabolism is determined (25). (2) With special attention to obtaining calmness in subjects, values 10% less than commonly accepted standards have been consistently obtained (22).

Many thousands of measurements indicate that the basal metabolic rate of normal individuals falls within fairly narrow limits. For a given age and sex, the basal metabolic rate (BMR) is most closely correlated with surface area which can be fairly accurately calculated from height and weight measurements. Other parameters have also been considered. Thus, Kleiber (26) considers $W^{0.7}$ (W = weight) to correlate more closely with BMR. (Since a major portion — 70–80% — of the heat loss takes place through the skin, it is not surprising that the BMR is proportional to the surface area. Surface area, for many geometric shapes, tends to vary roughly as the two-thirds power of volume or mass. In hot climates (27) the proportionality of BMR to surface area is less apparent.)

In any event, for a "normal" individual, the BMR may be predicted from standard tables to ± 10%, a variation which is no greater than that observed in different individuals on different days. In terms of Calorie requirements this means a spread of 300 Calories which is of considerable significance in weight gain. Newburgh points out that the custom of equating a low B.M.R. with hypothyroidism is not justifiable. A low B.M.R. is symptomatic of hypothyroidism, but often occurs in persons who exhibit every attribute of health and are completely free of myxedema and other hypothyroid or hypothyroidism symptoms. Finally, it must be emphasized that low B.M.R. *per se* need not cause obesity. In a healthy organism, as the outgo lessens the appetite diminishes proportionately. In experiments carried out by MacKay and Sherrill (27a) half of a group of rats, 107 days old, were subjected to complete thyroidectomy. These rats, together with the control group, were offered the same diet *ad libitum*. After 310 days, the controls had an average gain of 193 grams, while the thyroidectomized rats averaged a gain of only 178 grams. Furthermore, the bodies of the control rats contained 31 per cent of fat, whereas those of the thyroidectomized rats contained only 6.4 per cent fat.

Plummer (27b) recently published a statistical survey showing the relationship between myxedema and overweight. In a group of 200 patients, 61.5 per cent were overweight, but the greatest excess weight corresponded to the least depression of metabolism. Those patients with lowest B.M.R.'s weighed the least. Thus, those whose rates were not less than —28 per cent, were overweight by 11.5 per cent, whereas those whose B.M.R.'s were less than —38 per cent, were underweight by 14.7 per cent average.

The first days of thyroid medication brought an abrupt loss of weight, averaging 13 pounds per individual, bringing the average individual weight to a value less than standard. The loss in weight was due to elimination of fluid, indicating that excessive weight in hypothyroids is due to their abnormal accumulation of water. This is related to the known occurrence of edema — as the very name, myxedema, indicates.

Correlations have been attempted between the BMR values of obese and normal persons. If weight is used as the correlative variable, then obese individuals have a lower BMR than do normal controls. However, when BMR is compared per square meter of body surface there is little difference between the values for obese, normal or underweight subjects. No definite significance, accordingly, can be attached to BMR as an etiologic factor in obesity.

Of considerable interest in the dietary treatment of obesity are very recent studies at Michigan State College reported by Cedarquist (28) at the October, 1951 meeting of the American Dietetic Association. In these studies, it was found that when obese young women were put on a reducing diet (1200–

1400 Calories of low fat content, and supplying approximately 70–80 grams of protein, the BMR dropped in several weeks by 300–400 Calories. This drop in BMR was sufficient to markedly lower the rate of weight loss. With the use of a diet of the same or even slightly higher calorie value (approximately 1400 Calories), of slightly higher protein content (80 grams), but with the non-protein portion now richer in fat, no drop in BMR was noticed and weight reduction continued. A possible explanation for the drop in BMR on a low-fat reducing diet may be that, over an extended period of time, the body stores of such factors as the essential unsaturated fatty acids, of phospholipids or of their components, may be depleted. This, in turn, would result in a lowering of fat turnover and of general metabolic activity. Whatever the interpretation, the observation is of considerable significance in the treatment of obesity and, if confirmed, would seem to warrant sharp revision of the typical low-fat reducing diet.

Specific Dynamic Effect: Early workers observed that the heat output of individuals rises after meals. Originally this rise, amounting to 6–10 per cent of the caloric content of the ingested food, was attributed to the so-called "work of digestion." Subsequently, it was found that intravenous injection of amino acids or glucose also produced a rise in energy, even though the gastro-intestinal tract was thereby circumvented. Recent studies have shown that the specific dynamic action depends not only on the kind of food, i.e. protein, carbohydrate or fat, but also on whether these are fed singly or in combination. Thus, Glickman et al (29) using human subjects found that with meals supplying approximately 1000 Calories, an average specific dynamic action of 9.6 per cent or 103 Calories resulted with high carbohydrate meals (protein Calories providing only about 7 per cent of the meal); while with high protein meals (37 per cent of the total Calories derived from protein) the specific dynamic action was 169 Calories or 17 per cent of the caloric value of the ingested food. These values for mixed meals should be compared with the value of 4.7 per cent reported for fat (30) and of 32 per cent for proteins.

Forbes and Swift (31) using rats, also measured the specific dynamic action for the three food classes, individually and in mixed meals. They found that carbohydrate and protein had 12.5 per cent less, carbohydrate and fat 35 per cent less, protein and fat 54 per cent less, and all three 35 per cent less specific dynamic action effect than the specific dynamic action calculated additively for experimentally determined values of the individual nutrients. For example, the computed SDA per 1000 Calories of a mixture of beef protein (56%) and lard (43%) was 244 Calories, while the experimentally determined value was 113 Calories. For mixed meals, accordingly, the SDA of the individual nutrients has little significance.

The specific dynamic action of food depends not only on the nature and composition of the food but also upon the feeding history. It is sharply decreased following starvation or fasting (32). In a group of 50 normal men (29) on mixed diets, the SDA for breakfasts containing 500–900 Calories averaged 6.6 per cent of the Calories consumed; while for lunches of 800–1300 Calories, the SDA averaged 9.5 per cent.

The explanation for the specific dynamic action of foods is not clear at present. The old "plethora" theory first championed and then abandoned by Lusk (33) has new meaning in terms of modern knowledge of intermediate metabolism. Thus, with a post-prandial increase in the concentration of nutrients in the liver and in other tissues, an increase in metabolism (i.e. deamination, oxidation, etc.) would seem to be obligatory as a mass action effect, if nothing else. Such an interpretation is consistent with the effects of mixed diets, the effects of previous fasting, the effects of thiamine in increasing the specific dynamic action of glucose, and so on.

Attempts have been made to determine whether specific dynamic action varies in obese, normal and excessively lean individuals in order to evaluate its possible causative relation to obesity (34). These studies indicate that differences, if any, are two small to have an appreciable effect.

Luxuskonsumption: Grafe and coworkers (35) formulated the hypothesis that in normal or lean individuals ingestion of excess food caused an increase in general metabolic activity (apart from specific dynamic action). In this manner, the weight of normal individuals would tend to remain relatively constant in spite of excessive intake. Obese persons, on the other hand, were thought to have no such mechanism of "Luxuskonsumption" and, therefore, no means of burning up excess food.

Very few controlled studies have been made to distinguish between specific dynamic action and luxuskonsumption. Total metabolism measurements made for 33 days on a single lean individual by Wiley and Newburgh (36) by a method not altogether free from criticism (37), indicated no significant difference in metabolism as a result of super-alimentation.

Other workers (38, 38a) have recently observed that several lean individuals have been extravagantly over-fed under bed-rest conditions to minimize energy output without exhibiting a corresponding gain in weight. In this report, experimental data were not supplied.

It must be concluded that although this hypothesis has qualitative interest to explain the popular belief that some individuals can overeat without gaining weight, no definitely conclusive evidence has been demonstrated, either for or against its existence.

Muscular Activity: The energy expenditure of the muscular activity of work or exercise is both large and extremely different from one individual

to another. The caloric value for such activity, over and above the basal metabolism, ranges from 500 Calories per day for individuals engaged in light activity; to 5000–6000 Calories for men engaged in severe physical exertion, as for example, athletes, lumbermen, and others. Elaborate tables have been constructed for the energy expenditure corresponding to various activities. Keys (22) has criticized the use of these tables for purposes of obtaining by summation the energy requirements of individuals for the following reasons:

1. The values measured and listed in such tables are usually obtained by indirectly measuring heat output of individuals engaged for several minutes in an occupation such as hammering, sawing, painting, etc. The extension of this Calorie expenditure to an 8-hour day neglects the fact that actual working practice involves many breaks, rest intervals and changes in specific type of activity.

2. Most tables neglect the effects of body weight. In some types of activity, such as walking, the movement of the body itself constitutes a major factor in energy output. Therefore, a heavier man would require a greater amount of energy to walk the same distance than would a man weighing less. Such differences are not taken into account in tables listing the energy expenditure for various activities. On the other hand, in activities involving the lifting of external weights, the work output is relatively independent of body mass.

3. As a result of modern technology, energy expenditures for many of the activities listed have been sharply reduced.

4. With a 35–40 hour working week, only a fraction of the total energy expenditure stems from a given occupational activity.

Attempts have been made to explain obesity on the basis that obese individuals are more efficient in doing work. These attempts have been shown to be invalid because (1) on a gross physical basis, fat people are in general more awkward than lean individuals and in addition have to move extra body mass around in physical activity; (2) Actual demonstrations of heat output shows that obese persons expend extra energy for the same external work (39, 39a), that is, they have no more efficient coupling of muscular activity with metabolic oxidative energy.

In this connection it should be pointed out that the usual figure of 20–25% for the efficiency of the body as an engine is somewhat misleading. Experiments have demonstrated that this figure represents the mechanical equivalent of the heat produced by metabolic oxidation of food. It should be remembered, however, that only the free energy change, ΔF, of metabolic oxidation is available for work purposes. ΔF is less than the heat of oxidation, ΔH, by an entropy term, $T\Delta S$; i.e. $\Delta F = \Delta H - T\Delta S$. The ΔS of food metabolism is not known, but must be considerable in view of the high state of molecular organization of foods such as proteins, fats

and carbohydrates and the much lower state of organization of the end products, CO_2 and H_2O.

Hence, in terms of energy available for work the body is much more efficient than 20—25%.

Since the muscular efficiency of obese persons is not greater than that of normal persons, muscular activity is important as a factor in obesity only by its absence or lower incidence. This is in accordance with common observation. Most fat people, perhaps just because it is a greater effort to do so, do not move around or exert themselves to any great extent.

If food intake and energy output are not balanced, there is a gain or loss of weight depending on the direction of imbalance. Except in cases of extreme starvation, weight loss and gain involve predominantly the body fat. One pound of pure fat is equivalent to 4200 Calories. However, body fluid also changes with the supply of fat. By direct analysis on a cadaver, Mitchell *et al* (40) found that the adipose tissue contained 50.1 per cent of water.

The Calorie equivalent of body weight has been estimated by various workers to be from 2200 to 4200 calories per pound, the value of 3500 Calories being used by Rynearson and Gastineau (10) of the Mayo Clinic. Keys (22) states that 2300 Calories has been found in general to be equivalent to one pound change in body weight, corresponding closely to the 50 per cent water content cited. For men of normal, initial weight undergoing severe reduction, one pound is equal to 1800 Calories;* for such men gaining weight on a slightly overabundant diet, one pound is equal to 2350 Calories. For slightly fat men reducing mainly by exercise, 5300 Calories equal one pound of total body weight lost. These men exchanged muscle and water for part of the fat they lost.

Loss of weight on reducing diets is very often concealed by temporary water retention. In a case cited by Newburgh (18), a woman on a diet in daily deficit by 1200 Calories, lost no weight at all in ten days. However, in the next three days (10th, 11th, 12th day) she lost as much weight as she was expected to lose in the entire 12 days. Balance studies showed that water was the actual factor involved.

If the imbalance between food intake and energy output is not excessive, the balance tends to be restored. Thus if 100 Calories per day (as, for example, in one slice of bread and butter) is eaten in excess of the caloric requirements, this amounts to 36,000 Calories per year or about 15 pounds.

Actually, an increase in body weight involves also an increase in energy output since the basal metabolic rate and the cost of muscular activity will also go up. If the food intake remains constant (i.e., at only a 100 Calorie per day excess), a balance is eventually reached at a weight gain of only

*These men lost protein, containing roughly 80 per cent water, in addition to fat.

about 7—8 pounds. Similarly, in reduction, for a given Calorie deficit, the rate of weight loss will decrease as the total body weight diminishes.

Conclusion:

The major conclusion which can be drawn from the extensive work on this subject is that regardless of whatever other factors may be present, weight gain is caused by an imbalance between food intake and energy expenditure. It is difficult to predict the food intake required for any given individual. The constancy of mass itself is the only indication that food intake is calorically equivalent to energy output. It must be remembered, of course, that a condition of balance can exist at ideal weight, overweight or underweight. If weight is to be changed, by either gain or loss, either the food intake or the energy output, or both, require change in the appropriate direction.

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NEWS DIGEST

BIOCYTIN: Biocytin, a bound form of the vitamin, biotin, discovered in 1944 has been found to be a growth factor for several species of microorganisms. Recent reports indicate that the structure of the pure crystalline compound, isolated in trace amounts in December, 1949, has finally been determined. To complete the investigation about 5,000 pounds of yeast extract, representing about 25 tons of yeast, were processed. Chemical studies revealed that the vitamin is a complex of biotin with the essential amino acid, lysine.

—*Science 114,* 635 (1951)

FAT EMULSIONS FOR ORAL NUTRITION: Very finely homogenized fat emulsions suitable for oral nutrition in cases of severe undernutrition and underweight have recently been developed. These consist of an emulsion of 40 per cent peanut oil, and 10 per cent dextrose emulsified in water with soybean phosphatides and other stabilizers. Such emulsions have an average particle size of 0.5 to 1.0 microns and have been found to remain stable at room temperature for periods as long as six months. The extremely small size of these particles make this emulsion more easily tolerated than large dietary fat globules. This emulsion provides about 120 calories per ounce, or nearly 1,000 calories per 8-oz. glass. It may be taken as is or, preferably, in quantities of two tablespoonfuls in a glass of milk, several times daily. Clinical studies have shown that the emulsion is palatable, well-tolerated and has resulted in dramatic weight improvements in relatively short periods. Of 33 unselected normal adults in need of extra calories, weight gains ranging from 1 to 11.5 pounds in periods of from 5 to 63 days were observed.

—*J. Am. Diet. Assoc. 27,* 197 (1951)

IRON IN SPINACH: Recent findings indicate that spinach may once again be restored to favor as a source of iron in the diet. Hitherto, believed to be unavailable, the iron of spinach has been shown by actual studies with human subjects to be well utilized. In a group of six young women consuming an ordinary mixed diet for four weeks, followed by the same diet plus a serving of spinach each day, for a subsequent four week period, it was found that the percentage of iron utilized in the diet was the same in both cases. In each case, 12 per cent of the dietary iron was utilized.

—*J. Nutr. 44,* 383 (1951)